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IN VITRO COLD TRANSFERENCE OF BASES AND RESTORATIONS.(U)

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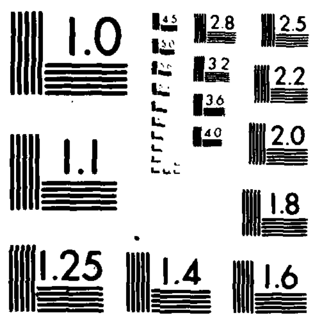

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IN VITRO COLD TRANSFERENCE OF BASES AND RESTORATIONS

BY

Donald D. Peters, COL, DC
and
Robert A. Augsburger, MAJ, DC

Dr. Peters, an Army colonel, is Assistant Director, Endodontic Residency Training Program, United States Army Institute of Dental Research, Washington, DC 20012

Dr. Augsburger is Chief, Department of Endodontics, William Beaumont Army Medical Center, El Paso, TX 79920. He is a major in the United States Army.

ABSTRACT

One-second applications of extreme cold (carbon dioxide snow) were made to amalgam and composite restorations with and without bases *in vitro*. Temperature changes were recorded intra-pulpally.

All bases under restorations reduced the intra-pulpal heat loss caused by external cold to a significant degree ($p<0.01$). The degree of reduction was much greater under the amalgam restorations, with all bases over 0.5mm reducing the intra-pulpal heat loss to less than one-half that lost if no base is present.

By far the greatest protection to temperature change caused by short-term episodes of cold occurred with the first 0.5-0.6mm of base. Under amalgam restorations, increasing an IRM base one extra millimeter only produced one-tenth the reduction caused by the first 0.62mm of IRM.

In the normal aging process, pulps of teeth become increasingly atrophic. This includes changes in cellular content, the increase of collagen bundles, calcific deposits, and progressive reduction in the size of pulp chambers.[1] The resulting tissue is incapable of responding to injury as well as young tissue.[2] A great deal of knowledge has been acquired on how traumatic episodes, such as deep caries or cutting cavity preparations without coolant, produce rapid aging-type responses of the pulp.[3-7] Robertson and others[8] showed the tremendous pulpal damage possible when the extreme heat of an electro-surgery unit is placed next to an unbased amalgam restoration for one second. Sudden temperature changes, although not of the extent of electro-surgery, can occur frequently during meals and severe weather. Unfortunately, little is known of the possible long-term effects on pulpal tissues caused by this type of chronic temperature changes when teeth have poorly based restorations. Langeland and others[9] did show that lack of symptoms does not mean lack of pulpal changes, and that atrophic pulps are more common in teeth with large restorations.[10] Just how these atrophic changes relate to the original caries and trauma of cavity preparation, or these factors in combination with the trauma of temperature changes associated with poor bases, is unknown. It would appear probable that long-term chronic exposures to sudden temperature changes may speed up these atrophic changes resulting in disease prone pulpal tissue.

Braden[11] did indicate that base thickness rather than type was more important for cold insulation. Voth and others[12] confirmed this and

showed that the thermal shock of cold transferred by amalgam is greatly reduced by zinc-oxide-eugenol, calcium hydroxide and zinc phosphate, but not by cavity varnish. Neither study addressed the importance of the reduction of thermal shock when the materials are in a cavity preparation with a dentinal floor. In addition, both studies measured the loss of heat caused by a constant cold source rather than short-term temperature shock which may be more clinically relevant.

It has also been shown that pulps in a stage of chronic irritation are susceptible to bacterial invasion.[13-15] Therefore, any procedure that reduces this chronic, even though sub-clinical, trauma to the pulp should be used.

The purpose of this study was to compare intra-pulpal thermal changes created by short-term application of carbon dioxide snow to unbased amalgam or composite restorations with the thermal change produced under based amalgam or composite restorations.

Methods & Materials

An *in vitro* method, as described previously,[16] was used to record temperature changes within the pulp chambers of teeth. The roots of six mandibular molars were removed 2 to 4 millimeters apically from the cemento-enamel junction, a silicone gel" was placed in the pulp chambers, and the teeth were mounted in acrylic jigs (Fig 1). Silicone oil has been shown to have the same thermo-conductivity as dentin.[17] During testing, the teeth in their acrylic jigs were maintained at body temperature on an aluminum plate 10.4 x 6.3 x 0.6cm (Fig 2).

The CO_2 pencil,[+] shown previously to be fast, accurate and consistent, was used for testing[16] (Fig 3). As a control prior to making the cavity preparations, each tooth was tested and the enamel plus dentin thickness recorded (Table 1, Fig 4). The thinnest measurements for the six teeth ranged from 2.7 to 3.5mm. Each test consisted of a 1-second carbon dioxide snow application 2 millimeters incisal to the cervical line in the center of the buccal surface mesio-distally. The intra-pulpal temperature change was recorded by a thermistor probe, 42.0 x 0.4mm, connected to a tele-thermometer.[$] The probe was placed intra-pulpally in contact with the dentin. The temperature changes were monitored for 90 seconds, and each test was repeated six times.

Oval Class V preparations 4.0 x 3.0mm were made in all six teeth with dentinal floor thicknesses ranging from 0.4 to 1.3mm (Table 1). Two coats of varnish[*] were placed prior to each restorative procedure.

All teeth were alternately restored to their original contour with each of the following:

Temporary Control:

Intermediate restorative material (IRM)[ϕ]

Amalgam:

IRM (average thickness of 1.65mm) under amalgam[#];

IRM (average thickness of 0.62mm) under amalgam;

Dycal[%] (average thickness of 0.53mm) under amalgam;

Dycal plus zinc phosphate cement[Δ] (average total thickness of

0.63mm) under amalgam;

Amalgam alone.

Composites:

Dycal (average thickness of 0.53mm) under composite[x];

Dycal plus zinc phosphate cement (average total thickness of 0.63mm) under composite;

Composite alone.

Six tests were made on each of the restorations. The restorations were carefully removed and the dentinal thickness rechecked after each series of tests.

Results

The original enamodentin thickness, dentin thickness after cavity preparation, and both controls, intra-pulpal temperature changes are given in Table 1. The thicknesses of all bases and bases plus dentin are given in Tables 2 and 3. The average intra-pulpal temperature decrease for each group of six tests for each tooth and each procedure is seen in Tables 4 and 5.

Intermediate Restorative Material (IRM) had a smaller temperature decrease (average 1.02F°) than the intact control (average 1.22F°) (Table 1) while all other combinations of bases and restorations had a significantly greater change of temperature (average 2.28 to 7.05F°) (Tables 4 and 5). Paired t-test showed that each procedure allowed a statistically significant ($p<0.01$) difference in temperature change from the temperature change allowed by the teeth without cavity preparation.[18] This means that a cavity preparation with a temporary

alone allowed significantly more protection to temperature change than intact tooth structure, while every cavity preparation with a base and permanent restoration allowed significantly less protection than intact tooth structure.

Bases under restorations always reduced the temperature transference although this was much more significant for the bases under the amalgams (Tables 4 and 5). That is, an average of 0.63mm of Dycal and zinc phosphate base reduced the temperature transference an average 3.47F° over the temperature transferenced allowed by amalgam alone (7.24F° to 3.37F°), while the same thickness of Dycal and zinc phosphate under composite only reduced the temperature transference an average of 0.59F° over the temperature transference allowed by composite alone (3.32F° to 2.73F°). While paired t-test showed both reductions to be statistically significant (p 0.01), it is also obvious that the 3.47F° should be of far greater physiological significance than the 0.59F°.

In the teeth with bases of average thicknesses of 0.53, 0.62 and 0.63mm under amalgam, the range of average temperature change was only 3.24 to 3.47F° (Table 4). In the instance where the thickness of a temporary (IRM) under amalgam was increased an average 1.03mm, or from 0.62mm to 1.65mm, the average temperature change only decreased an average 0.40F°, or from 3.25F° to 2.85F° (Table 4). Dycal 0.53mm thick under amalgam was almost equally resistant to temperature transference as Dycal and zinc phosphate 0.63mm thick under amalgam (3.47F° vs. 3.37F°) (Table 4). Dycal 0.53mm thick under composite was more resistant to temperature transference than Dycal and zinc

phosphate 0.63mm thick under composite (2.20F° vs. 2.73F°) (Table 5).

The tests generally showed greater intra-pulpal temperature change with decreased thickness of dentin. There was an exception in only six of the 54 series of tests made on teeth with restorations. In each of the six cases, there was a corresponding increased thickness of base which should account for the decrease in temperature change (Tables 1-3).

Maximum temperature changes for both controls and restored teeth with bases occurred consistently between 15 and 20 seconds. For amalgams and composites without bases, the maximum temperature change occurred between 10 and 15 seconds.

Discussion

The findings of this study are not surprising, but they underscore the necessity of placing bases under restorations to insulate against thermal changes. Bases were shown to universally reduce the internal heat loss caused by external cold. The net effect of bases under composites was less dramatic than under amalgam, however, all the bases did reduce intra-pulpal temperature change. Therefore, it appears that for maximum pulpal protection to temperature changes, bases should be used in any preparation that enters the dentin. However, it must be emphasized that while the paired t-test showed a statistically significant difference in the protection offered by the various materials just how clinically or physiologically significant the results are is still unknown. For instance, while the decrease in temperature changes allowed by IRM when compared to that allowed by the

intact tooth was statistically significant, the actual difference was only an average 0.20F°. Still, since avoidance of excessive atrophic changes is desirable, maximu protection following cavity preparation appears indicated.

Increasing the thickness of the IRM base under amalgam from 0.62mm (average) to 1.65mm (average), only reduced the temperature change slightly (an average of 0.40F°). This is only one-tenth the 3.99F° change achieved by 0.62mm of IRM. This would appear to conflict with the findings of Braden[11] and Voth et al.[12] Both conflicts are possibly explained by the fact that in this study the extremely cold carbon dioxide snow was placed on the restoration for only 1 second. In both previous studies, the cold was placed on the restoration for a long period (14 seconds to 3 minutes) and changes recorded during this time. Also, Braden[11] tested only bases without permanent restorations while Voth and others[12] compared 0.16mm thick bases to bases 1.4mm thick. The present study, while not including extremely thin bases, evaluates how bases function to protect the pulp in a more clinical situation. That is with the base placed in teeth, under a permanent restoration, over a dentinal floor of varying thickness, and subjected to short episodes of sudden temperature change. Basically, it shows that under these conditions all bases over 0.5mm thick work well in forcing the heat replacement to occur laterally or from a greater area of tooth structure than directly from the pulp. But it also confirms that increasing base thickness does increase pulpal protection.

This study also suggests that Dycal may offer slightly better

thermal protection than zinc phosphate cement. Dycal of an average thickness of 0.53mm under amalgam allowed only slightly more temperature change than Dycal and zinc phosphate of an average thickness of 0.63mm under amalgam (3.47F° vs. 3.37F°). Two of the six teeth actually allowed less. Under composite with the same thicknesses of base, the Dycal allowed even less (average change 2.28F° vs. 2.73F°) thermal changes. It must be emphasized that this is only suggestive and would need more detailed investigation.

As noted in 48 of 54 cases, the transference of temperature increased with a decrease in thickness of dentin. In each of the six cases where there was a decrease in temperature transference with a decrease in dentin thickness, there was a corresponding increase thickness of base or temporary (Tables 1-3). This appears to reconfirm what already was shown, that the base allowed less temperature change than the tooth structure.

An IRM restoration alone afforded far greater thermal protection than the 1.65mm (average) IRM base under amalgam. Therefore, in deep (indirect pulp cap) cavities a temporary restoration may be indicated for a period to minimize temperature trauma while the pulp responds with peritubular and secondary dentin. This may minimize excessive atrophic responses, allowing the pulp to remain in a healthier state better able to withstand future trauma such as loss of fillings, recurrent caries, or operative procedures.

Copal varnish was used under restoration throughout this study only to duplicate the clinical situation where it has been shown of

value even though it does not affect temperature transference.[19]

Summary and Conclusion

An *in vitro* technique was used to evaluate temperature transference through various restorations and bases. All tests were repeated six times using a 1-second application of CO_2 snow on the surface of the restoration. Bases in all cases decreased the temperature transference significantly. This was most significant in the cases with an amalgam permanent restoration.

Under amalgam restorations there was an average 3.99F° reduction in temperature change with 0.62mm of base while increasing the thickness 1.03mm more only increased the reduction in average temperature change one-tenth as much or 0.40F°. Therefore, while increasing the thickness of base did consistently increase pulpal protection after 0.62mm, the degree of protection dropped significantly at least to short episodes of extreme cold.

A temporary restoration alone did give significantly more protection than the thickest base under an amalgam (1.02F° change vs. 2.85F°).

The best protection by a base under a permanent restoration in this study (an average of 0.53mm Dycal under composite) still allowed an average of 2.28F° temperature change after short episodes of extreme cold. In comparison, temperature transfer through intact tooth structure averaged 1.22F° change while the cavity preparation restored with a base alone allowed only 1.02F° change. Therefore, in conclusion:

1. For maximum pulpal protection, bases are indicated under any

restoration into the dentin.

2. A temporary alone gives significantly more protection than a thick base plus a permanent restoration.
3. The insulating effect of 0.5 to 0.6mm of base affords great intra-pulpal protection to short-term thermal changes.
4. Under restorations, increasing the thickness of the same base did consistently increase the protection to short-term thermal shock. Its significance was greatly reduced after 0.5mm.
5. This data appears to support the hypothesis that sudden trauma of temperature changes could cause additional damage to a pulp already damaged by deep caries and cavity preparation. This could result in a tooth even less capable of a healing response to future trauma.

Table 1. Average in Fahrenheit degrees (ΔF°) temperature change after one-second application of the carbon dioxide snow on controls (no cavity preparation) and with temporary restorations (IRM).

Tooth #	Enamodentin Thickness (mm)	Cavity Prep. Dentin Thickness (mm)	IRM Thickness (mm)	CONTROLS Enamel ΔF°	CONTROLS IRM ΔF°
1	3.4	1.3	2.1	1.00±0.100	0.92±0.075
2	3.3	1.3	2.0	1.08±0.084	0.70±0.089
3	3.2	1.0	2.2	1.18±0.110	0.97±0.163
4	3.2	1.0	2.2*	1.25±0.164	0.89*±0.082
5	2.7	0.4	2.3	1.42±0.240	1.35±0.123
6	2.7	0.6	2.1	1.38±0.098	1.12±0.117
		Averages of Temperature Changes		1.22	1.02

*First case where temperature change was less than in teeth with thicker dentinal floors (teeth #1 and 2).

Table 2. Thicknesses in millimeters of dentin and bases under amalgam restorations.

Tooth #	Dentin	Thick IRM	Dentin + IRM	Thin IRM	Dentin + IRM	Dycal	Dentin + Dycal	Base*	Dentin + Base
1	1.3	1.5	2.8	0.5	1.8	0.5	1.8	0.5	1.8
2	1.3	1.5	2.8	0.4	1.7	0.5	1.8	0.5	1.8
3	1.0	1.7**	2.7	0.7	1.7	0.5	1.5	0.7	1.7
4	1.0	1.7**	2.7	0.7	1.7	0.7**	1.7	0.7	1.7
5	0.4	1.8	2.2	017	1.1	0.6	1.0	0.7	1.1
6	0.6	1.7	2.3	0.7	1.3	0.5	1.1	0.7	1.3
Average Base		1.65		0.62		0.53		0.63	

*Dycal plus zinc phosphate base. Dycal measured 0.2mm in each case.

**Three cases where temperature change was less than where dentinal floors were thicker (teeth 1 and 2). All three cases had a corresponding 0.2mm thicker base.

Table 3. Thicknesses in millimeters of dentin and bases under composite restorations.

Tooth #	Dentin	Dycal	Dentin + Dycal	Base*	Dentin + Base
1	1.3	0.5	1.8	0.5	1.8
2	1.3	0.4	1.7	0.5	1.8
3	1.0	0.5	1.5	0.7**	1.7
4	1.0	0.7	1.7	0.7**	1.7
5	0.4	0.6	1.0	0.7	1.1
6	0.6	0.5	1.1	0.7	1.3
Average Base		0.53		0.63	

*Dycal plus zinc phosphate base. Dycal measured 0.2mm in each case.

**Two cases where temperature change was less than where dentinal floors were thicker (teeth 1 and 2). Both cases had a corresponding 0.2mm thicker base.

Table 4. Average in Fahrenheit degrees (F°) temperature change after one-second application of carbon dioxide snow on amalgam restorations with the standard deviations.

Tooth #	IRM Base 1.65mm ΔF°	IRM Base 0.62mm ΔF°	Dycal Base 0.53mm ΔF°	Dycal + Zinc Phosphate Base 0.63mm ΔF°	Amalgam No Base ΔF°
1	2.76±0.151	2.92±0.271	3.00±0.210	2.82±0.160	6.27±0.345
2	2.68±0.184	2.88±0.223	3.38±0.098	2.85±0.176	6.17±0.345
3	2.47*±0.175	3.00±0.190	3.50±0.237	3.33±0.206	7.50±0.303
4	2.43*±0.163	3.10±0.245	2.92*±0.325	3.28±0.239	7.08±0.387
5	3.25±0.152	3.30±0.310	3.65±0.281	3.52±0.223	8.07±0.388
6	3.52±0.204	4.28±0.430	4.35±0.321	4.42±0.335	8.35±0.446
Average	2.85	3.25	3.47	3.37	7.24

*Three cases where temperature change was less than in teeth with thicker dentinal floors. In each case the base was 0.2mm thicker than in teeth #1 and 2 (Table 2).

Table 5. Average in Fahrenheit degrees ($\Delta F°$) temperature change after one-second application of carbon dioxide snow on composite restorations with the standard deviations.

Tooth #	Dycal Base 0.53mm $\Delta F°$	Dycal + Zinc Phosphate Base 0.63mm $\Delta F°$	Composite No Base $\Delta F°$
1	1.88±0.204	2.62±0.147	2.93±0.204
2	1.98±0.117	2.67±0.175	2.88±0.117
3	2.52±0.194	2.55*±0.138	3.37±0.234
4	2.17±0.121	2.20*±0.210	3.20±0.245
5	2.50±0.089	3.08±0.075	3.63±0.207
6	2.65±0.123	3.27±0.151	3.93±0.356
Average	2.28	2.73	3.32

*Two cases where temperature change was less than in teeth with thicker dentinal floors (teeth 1 and 2). In both cases the base was 0.2mm thicker than in teeth #1 and 2 (Table 3).

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" GC Silicone Compound Z-5, GC Electronics, Rockford, ILL 61101

+ Odontotest(R) Union Broach Corp., 36-40 37th Street, Long Island City, NY 11101

$ Tel-Thermometer, V.S.I. Model 43TF, Yellow Springs Inst. Co., Inc., Yellow Springs, Ohio 45387

* Copalite Intermediary Varnish, Teledyne Dental Products, 1550 Greenleaf Ave., Elk Grove Village, ILL 60007

ϕ Intermediate Restorative Material, The L. D. Caulk Co., Milford, DE 19963

Dispensalloy(R), Johnson and Johnson, Dental Products Co., East Windsor, NY 08520

% Dycal, The L.D. Caulk Co., Milford, DE 19963

Δ Fleck's Zinc Cement, Mizzy Inc., Clifton Forge, VA 24422

x Adaptic(R), Johnson and Johnson Dental Products Co., East Windsor, NJ 08520

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COL Donald D. Peters
Assistant Director, Endodontic Residency Program
US Army Institute of Dental Research
Walter Reed Army Medical Center
Washington, DC 20012

LEGEND

Fig 1A Two mandibular molars mounted in an acrylic jig. Tooth on left has cavity preparation and tooth on right has amalgam restoration.

Fig 1B Four mandibular molars mounted in an acrylic jig. All four teeth have composite restorations.

Fig 2 Two mandibular molars in an acrylic jig mounted on the aluminum plate heat source.

Fig 3 Carbon dioxide snow apparatus.

A. Outer plastic holder which attaches to CO_2 tank.

B. Carbon dioxide pencil which carries the carbon dioxide snow. Pellet at end is exact size of carbon dioxide testing surface which is placed against the tooth.

C. Plunger to condense the carbon dioxide snow.

Fig 4 Boley gauge being used to measure enamo-dentinal thickness.

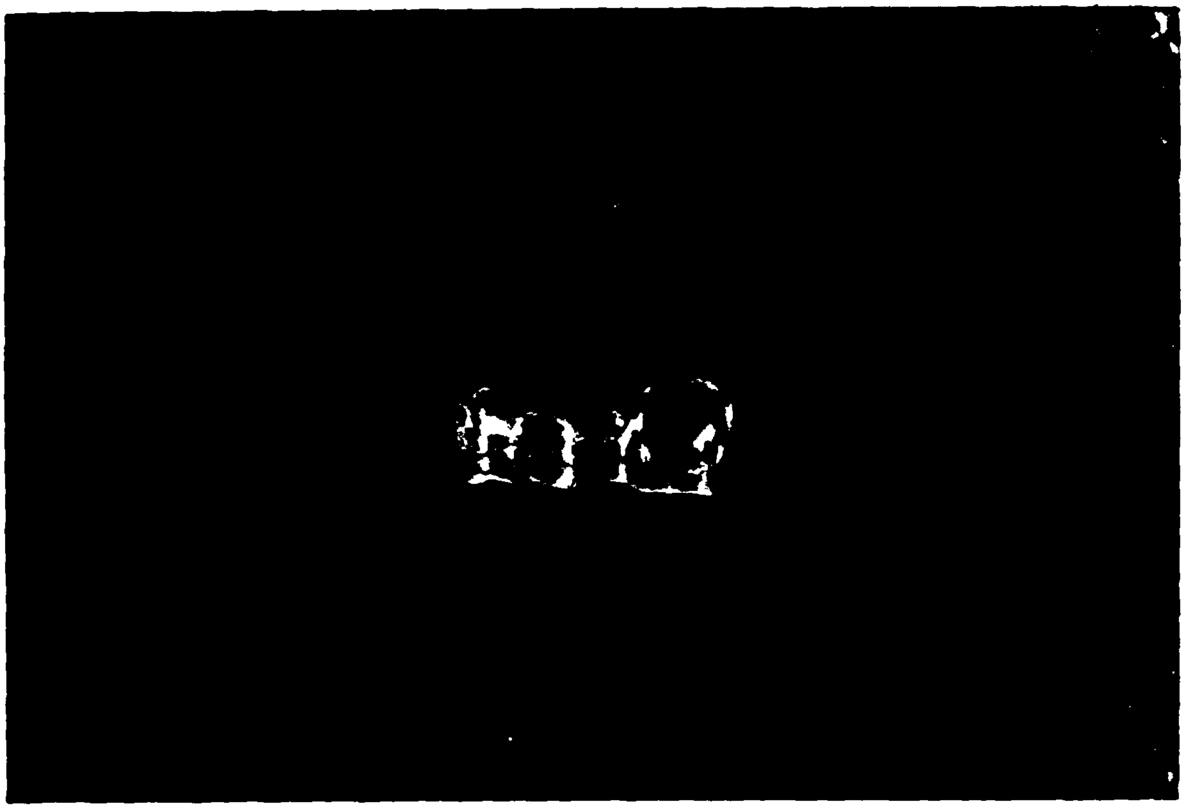

FIGURE 1

FIGURE 1B

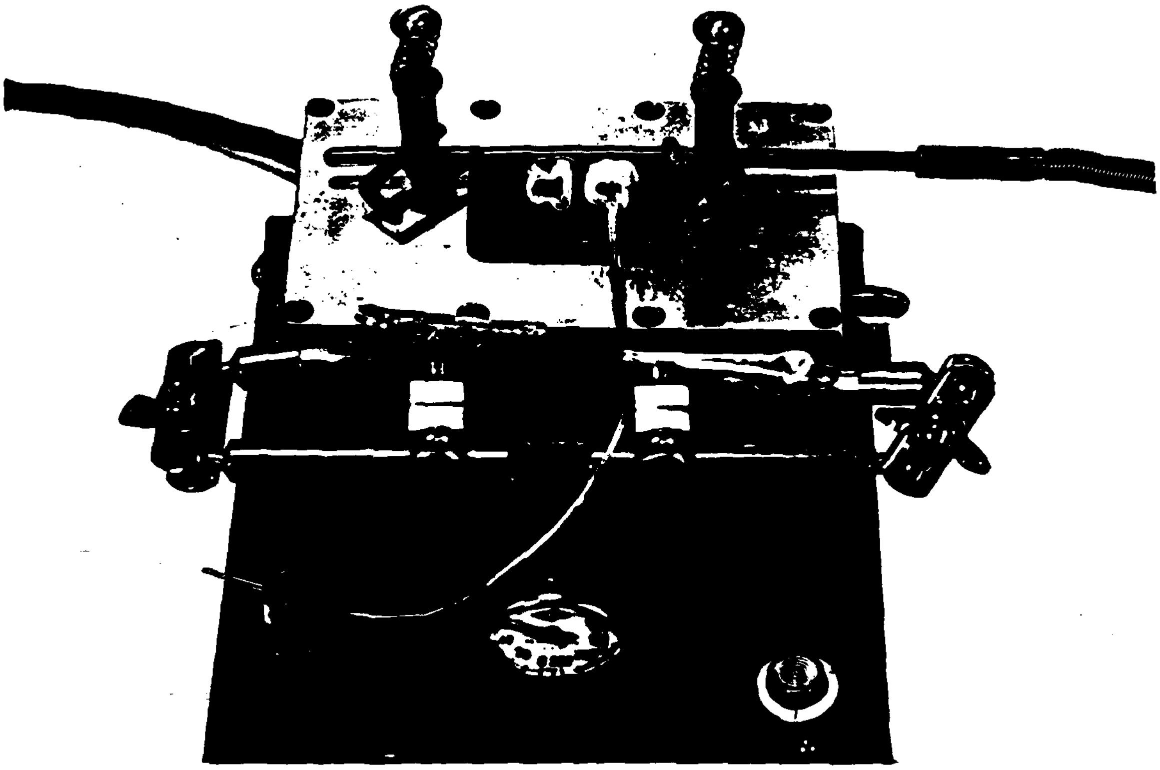

FIGURE 2

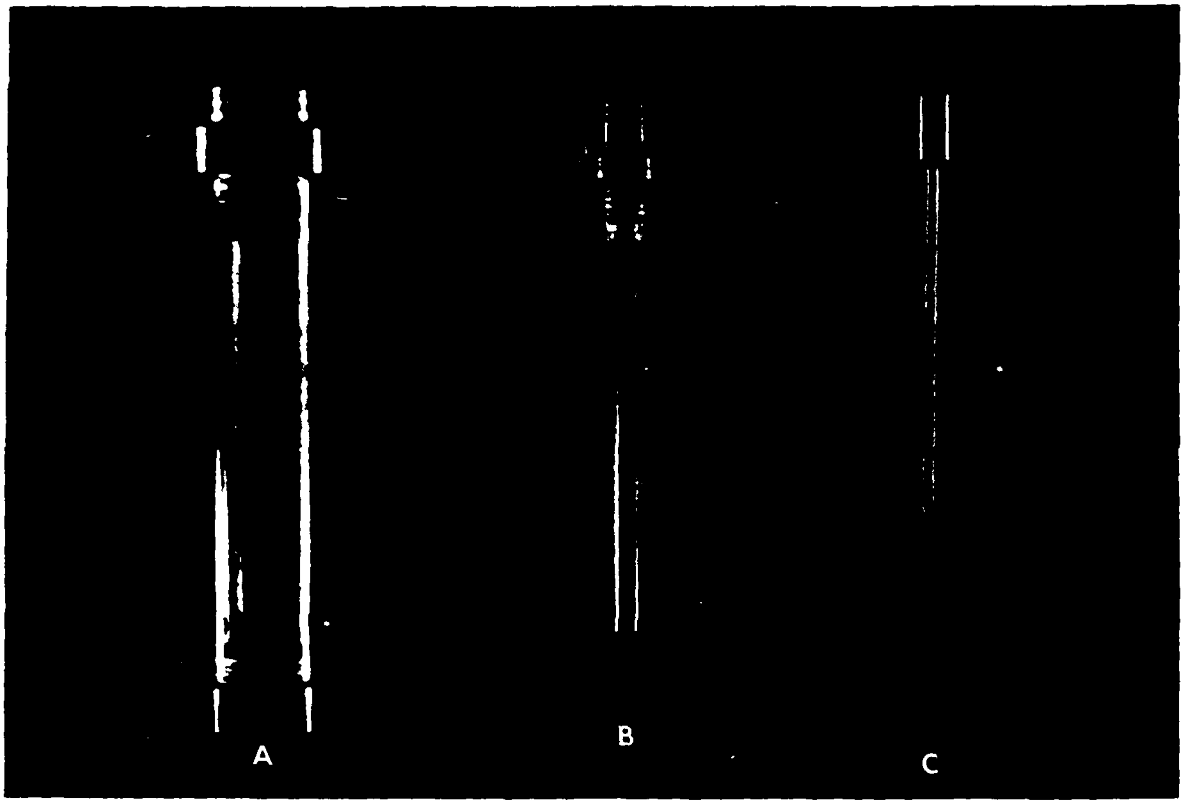

FIGURE 3

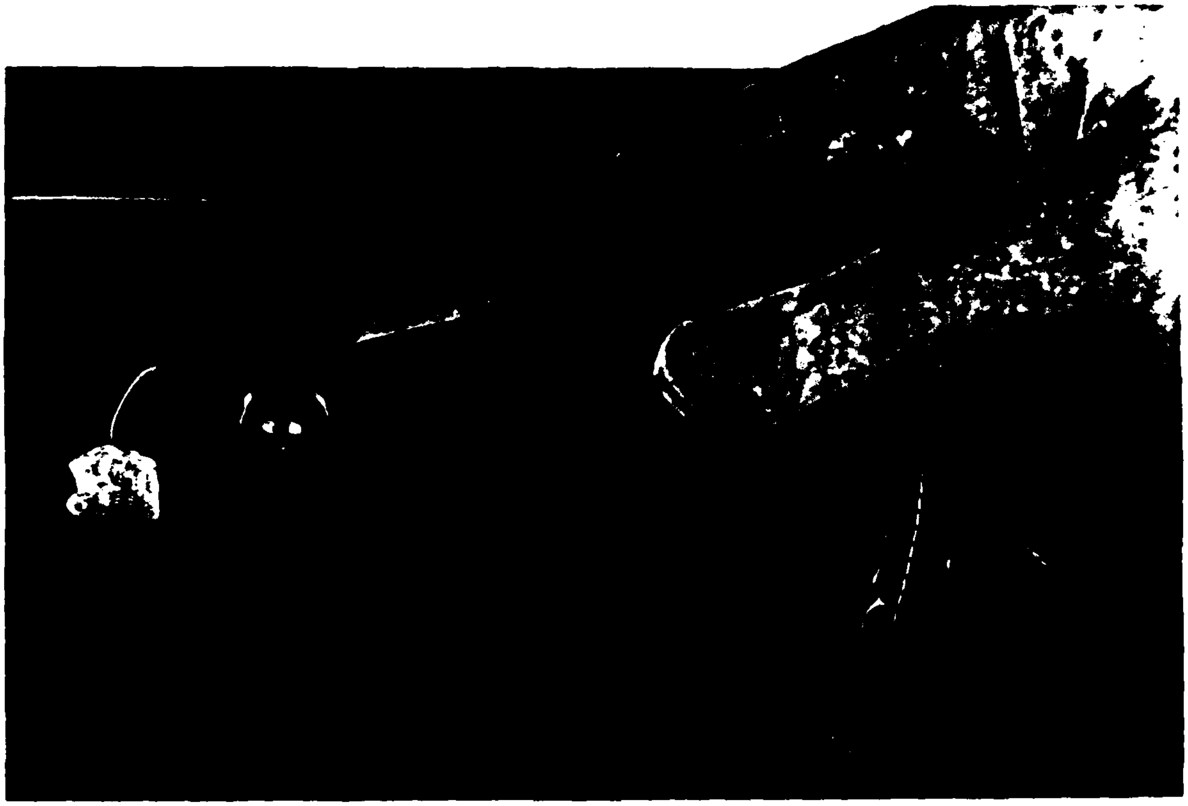

FIGURE 4

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